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MENACE OF ANTI-SHIP MISSILES AND SHIPBORNE LASER WEAPONS

by

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MENACE OF ANTI-SHIP MISSILES AND SHIPBORNE LASER WEAPONS

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ABSTRACT

This paper discusses the menace of anti-ship missiles, the difficulties of operational shipborne short-range anti-missile defense systems, and a survey of the development of shipborne laser weapons.

I. Introduction

During the Third Middle East War in 19067 Israel's destroyer "Ailate" (phonetic) was sunk by a "Styx" missile launched from a small speedboat. In the 1971 war between India and Pakistan, India launched 13 "Styx" missiles, 12 of which hit their targets. In the 1973 Arab-Israeli war Israel's "Jiaboli" (phonetic) anti-ship missiles sand five arab ships. In the Falkland Island War in 1982 the British destroyer "Sheffield" and transport "Atlantic Transporter" were sunk by "Exocet" missiles. From the third Middle East War to the Gulf War, a total of 170 to 190 anti-ship missiles have been launched, sinking more than 20 ships and boats. Therefore, how to deal with anti-ship capabilities to improve combat capabilities and survivability is the developmental direction for modern naval ships.

II. The ever increasing threat of anti-ship missiles

Anti-ship missiles are flying bombs equipped with guidance systems directed against ships. Modern naval combat has demonstrated that anti-ship missiles are highly reliable and tremendously destructive. According to incomplete statistics at the end of 1990, there were 77 countries in the world which possessed anti-ship missiles, and the total number of anti-ship missiles coming to about 30,000. It is estimated that in 1997 the number of countries with anti-ship missiles will increase to 100, and the total number of anti-ship missiles will grow to 50,000. these missiles have replaced the ship guns as the primary offensive weapon. Their primary characteristics are:

1. Small and light, and can be launched from any platform

Because of the developments in microelectronics, small nuclear warheads and small high efficiency turbojet engine technology, anti-ship missiles are small and light, about one order of magnitude smaller and lighter than a ballistic missile with the same range. Also, because of the powered flight of the missile, launch recoil is light, and they can be launched from the ship deck on the surface of the water, from submarines under the water, or from aircraft (or helicopters) in the air. They can also be launched from trucks on land. Because they are small and light, the various carrier platforms can carry large numbers of these missiles. For example, a submarine or a bomber can carry ten to several dozen to launch a saturation attack, which is extremely difficult to defend against.

2. Small and fast, with strong breakthrough capability

Anti-ship missiles present a small radar cross section, from $0.05m^2$ to $0.10m^2$. Stealth missiles currently being developed may be as small as $0.01m^2$. However, current radars were designed for large cross sectional area aircraft, so fire control radars have an operational range of only several kilometers against anti-ship missiles. At the same time, anti-ship missiles are very fast, currently from sub-Mach speeds to Mach 3, and before long they will reach Mach 2 to 5. Fire control systems currently in service cannot intercept them. Also, anti-ship missiles attack from two blind spots of radars - the ship water line and vertically from above. That is, cruising just above the surface and large angle dive. For example, for a wave-hopping missile with a small radar cross section and a terminal flight altitude of two meters, it would be difficult to detect even by modern radars with moving target display characteristics and can inhibit ocean interference waves and have high detection capabilities. Although fire control radars can track these missiles, when they appear on the scope, the target darts back and forth, and it is difficult to get a precise fix, and precise target parameters cannot be obtained. Surface reflection false return waves can result in proximity fuses detonating at the wrong time, and anti-missile missiles have a hard time in guidance toward the target. Tests and exercises have both demonstrate that even with extremely good ideal conditions, the rate of detection and intercept of anti-ship missiles is very low. In summary, because their radar cross section is becoming smaller and smaller and their speed faster and faster, and with their concealed path, they are not easy to detect, track and intercept. Therefore, anti-ship missiles have a very strong capability to break through defenses.

3. Long range, can be launched outside air defense firepower

Anti-ship missiles have ranges from 30 to 800 kilometers, while the gun with the longest range, the United states 280 mm gun which fires atomic shells has a firing range of 32 kilometers. Therefore, the absolute majority of anti-ship missiles can be launched from outside the range of the ship's air defense fire power. Anti-ship missiles with a range of 30 to 50 kilometers are mounted on small missile launches or escorts and can be launched at a target within the range of the ship's radar. Anti-ship missiles with a range of 500 km or more are mounted on submarines or large surface ships, and can be launched outside the defenses of the targets aerial formation.

4. They are intelligent, and have good combat effectiveness

The terminal homing radar parabolic antenna of anti-ship missiles have the capability of automatically mounting the antenna shield in order to reduce the radar cross section. They can be loaded with launch ballistics in advance in order to conceal the location of the launch platform. Terminal homing radars have frequency shift capability. When the homing radars are jammed, they can automatically switch to tracking jamming sources or to electronic optical automatic modes. They are equipped with logic circuitry to differentiate between radar jamming and the actual target. They are equipped with logic circuits which alter the missile velocity what they come within a certain distance from the target. They are equipped with logic circuits which differentiate between infrared tracers and the real target's characteristics. They can have their terminal attack trajectory programmed in advance, increasing the destructive capability of the bomb, such as avoiding special armored locations on the enemy ship, and finding weak links in order to increase the combat effectiveness of the warhead.

5. High precision, highly destructive

The destructive capability of missile is determined by the precision of the guidance and the power of the warhead. The guidance of anti-ship missiles is intermediate inertia guidance and terminal frequency shifting radar (active, semi-active or passive), infrared target-seeking, television and laser guidance, as well as low light television and composite guidance currently under development[1]. In addition to semi-active radar target-seeking and television guidance, the other forms all have fire-and-forget capability. Guidance precision is one order of magnitude higher than ballistic missiles, and precision can be within 10 meters. Warheads are shaped charge armor piercing, semi-armor piercing and high explosive. They may also be mixed with nuclear warheads. Hits by one or two anti-ship missiles can destroy a ship.

III. Problems with current anti-missile systems

Current ship gun and missile anti-missile defense systems both are unable to intercept anti-ship missiles.

The Italian Navy with industrial assistance has proposed using a gun as the final line of defense against anti-ship missiles and the ideal terminal defense.

Guns are traditional air-defense weapons. They have wide applications, are cheap, have a high rate of fire, and a broad field of fire. A number of nations use advanced radar and optoelectronic fire control systems on their ships as terminal defense. In the Falkland Island War England's Sheffield was equipped with three dense burst of fire systems which were purchased at a cost of 4.8 million Dollars in an attempt to increase the ship's defensive capabilities. However, these systems have not yet been tested under actual fire.

The eight major foreign close range gun anti-missile systems are the MK15-1 dense burst, the "NAVAL GUARD" (Haishangweishi), the "DADUO" (phonetic), the SAMUSI (phonetic), the MEILUOKA (phonetic), the TELINIDI (phonetic) and the CADS-N-1[2]. The first seven are called first generation shipborne gun anti-missile systems, and the eighth is replacement equipment for former Soviet Union 1970 first generation, and is a second generation ship anti-missile system. It has a rate of fire 1. to 2.5 times faster than first generation systems. All of these systems are direct hit systems and not indirect hit systems. They used zenith technology and a unified structure as well as combined shell and gun, and increased the capacity of the magazine[3]. However, they are barrel energy weapons and there has been no change in their firing accuracy, and the mechanism of direct hit damage has not changed. Therefore, dynamic projectile terminal effect and anti-missile effectiveness both require thorough research, and await testing under actual combat conditions. Whether first or second generation systems, the primary problem with close range ship gun anti-missile systems is the close range and slow reaction time of the detection and tracking of the anti-ship missile, and the inability to intercept. The MEILUOKA (phonetic) system has a response time of 4.2 seconds, but this is only from the time of detection until the guns are directed toward the specified point, and does not include the time required from the launch control system receiving the order to fire until the firing procedure is begun. The dense burst reaction time is six seconds, but some data shows it to be 10 seconds, and other data says it is 3.5 seconds. A definite reaction time is given for the DADUO (phonetic) system, and a definite picture of the seven time segments which compose reaction time is also given. The "DADUO" (phonetic) system intercept range is 900 to 3000 meters, but the proximity fuse shells theoretically require a minimum of two to 4.5 seconds to destroy the data of the missile guidance system to cause the missile to deviate from its course and miss the target 99 percent of the time. If an "EXOCET" missile travelling at Mach 0.95 attacks, then the close range intercept distance should be 340 X 0.95 X 4.5 = 1500 (meters). The long range intercept time when the target is three kilometers away is 16 seconds. However, within 16 seconds, the target moves 5.2

kilometers closer, and the minimum range for the search radar to detect the target is 8.2 kilometers. When the target is 1.5 kilometers away, short range intercept time is 14.5 seconds, during which time the target will move 4.5 kilometers closer. When it is less than 4.7 kilometers, the continued intercept time is only 4.5 seconds (for a target travelling at Mach 0.95), and only 45 rounds can be fired, limiting firepower. However, anti-ship missiles under development have a radar cross section of only $0.1m^2$, and wave-hopping flight speed will be Mach two to Mach three (for large angle dive missiles, the speed will be as much as Mach three to Mach five), then the "DADUO" system detection range will drop from nine kilometers to six kilometers. Then the Mach two or Mach three missile will move 340 X 2 X 4.5 - 3000 (meters) or 340 X 3 X 4.5 - 4600 (meters) closer to the ship from the time it is detected at six kilometers in only 4.5 or 1.4 seconds. This is much less than the sum of the system reaction time and the projectile flight time. Since short range intercept range is equal to or greater than long range intercept tome, intercept range is zero or negative, and reaction is impossible.

Naturally, some of these ship gun anti-missile systems have a direct hit system. This does not require consideration of the aforementioned two to 4.5 second time restriction for the missile to deviate from the target. However, their guns are smaller than those of the "DADUO" system, and effective firing range drops from the 8000 meters of the "DADUO" system to 3000 to 1486 meters, and long range intercept range drops from the 3000 meters of the "DADUO" system to 1800 to 1200 meters. Therefore, in summation, the other seven types of ship gun system also have similar problems to varying degrees. Also, after the shells are fired, they cannot deal with the avoidance maneuvers of the incoming missile. The fuses and charges of the 40 mm, 35 mm and 20 mm guns cannot penetrate missile warheads which are equipped with armor. In summation, close range ship gun systems cannot effectively defend against anti-ship missiles.

Compared to ship guns, shipborne anti-missile have a higher hit rate and are more powerful. However, surface defense missiles do not have the capability to counter anti-ship missiles. This point was demonstrated during sea combat of the Falkland Island War. The British "HAIBIAOQIANG" (phonetic) missiles were unable to detect wave-hopping missiles because of their excessive reaction time, in addition to the search radar reaction time, the reaction time was as much as 19 seconds, and because the missile semi-active homing head did not have look-down capability and could not track wave-hopping targets, and especially because warning radar had poor low altitude capabilities. For example, the "SHEFFIELD"'s warning radar never did detect the long-range "EXOCET" missile which was fired from 70 kilometers away. It was not visually detected until it had approached to 1500 meters. At this time there were only five seconds before impact, and the "HAIBIAOQIANG" missiles were useless, so the crew watched as the ship was hit, exploded, caught fire and sank.

There are a number of different types of point defense missiles which have a certain degree of anti-missile capability. However, the basic design of the widely deployed "Sea Sparrow" missile is fairly old, and it cannot effectively defend against modernized anti-ship missile attacks. However, the first point defense missile believed effective against anti-ship missiles - the "sea Wolf" missile was not effective at all in the Falkland Island War, not shooting down a single anti-ship missile. Because the maximum intercept range of the "Sea Wolf" is five kilometers, and it requires a 15 kilometer warning of a wave-hopping missile attack, and 15 kilometers ordinarily the sighting limits of destroyer or escort radars, and at the same time, these current radars are not able to discriminate between extremely small wave-hopping missiles and surface noise, and these systems have a long reaction time, generally ten to 14 seconds, and these missiles all have a blind zone, which begins when the missile leaves to tube until it enters the fire control system guidance beam and flies to the required course. Within the blind zone the missile cannot be controlled and cannot be pre-programmed to enter the target's path. Also, the missile requires a fairly long time for power supply time and for preparatory operations, and cannot be launched immediately.

Therefore, close range missile anti-missile systems currently employed have difficulty coping with the current sub-sonic "EXOCET" missile, and if the speeds of the anti-ship missiles exceed Mach 1.8, then they will be useless.

IV. Anti-missile technology always lags behind missile technology

The two currently employed anti-missile systems have limited anti-missile capability. Therefore, facing a missile attack a ship has little hope of survival, especially if there are a number of anti-ship missiles in an almost simultaneous dense saturation attack.

There is also developmental potential in close range missile systems, and it is still possible to make some advances to cope with certain current anti-ship missiles, such as increasing the velocity of the missile, using composite guidance, using a unified search and tracking system, selecting phase controlled array radars, improving capability of detecting super low altitude small targets, switching to helicopter launch mode, shortening reaction time and all directional counterattack capability. However, enhancing the capabilities of defensive missile systems will only encourage advances in attack missiles, and in the 21st century anti-ship missiles will have the following characteristics:

They will use helicopter launch technology, they will have large storage capacity, will have a high launch rate, will be able to launch immediately and will be able to attack in all directions. They will have increased range, increased speed and will take less time to reach the enemy. They will use stealth technology, and in addition to wave-hopping flight, they will also be capable of level snaking flight and of maneuvering high low high and low high low, they will use under water attack at the terminal end, they will use acoustic or magnetic signal for terminal guidance, greatly increasing concealment in their attacks. The missile engines will use exhaust smoke abatement and exhaust gas cooling to reduce the engine's infrared signature. The size of the missiles will become smaller, eliminating the straight angle structure, and the nose surface will be a beehive structure, and the body will be coated with a microwave absorbing material to reduce the radar cross section. Artificial intelligence technology will be used for intelligent capability for terminal guidance and the guidance head will be capable of inference and decision making, to form an artificial intelligence expert system which can automatically search, recognize, capture and track and attack a target in a complex environment. They will be capable of selecting their own priority target according to degree of threat. They will be equipped with shrapnel warheads with time delay fuses, exploding after they have penetrated the body of the ship to increase their destructive power. They will be equipped with shaped charge warheads which will concentrate energy on a certain point of the ship to destroy the armor protection at an important location on the ship. They will become standardized, interchangeable, systemized and modularized in order to reduce research costs, reduce the refitting cycle and to reduce the amount of space taken up by the system.

Just speaking of increasing missile velocity, the former Soviet Union has continued development of the Mach 5 hyper velocity missile systems the SA-N-6 and the SA-N-7. They can shorten flight time, and thus correspondingly shorten the radar warning time required. However, there are limits to how much the time can be shortened, and the potential for this is not great. However, anti-ship missile velocities are also constantly being increased, and their radar cross sections are being reduced by orders of magnitude, greatly reducing the warning times radars are able to achieve, with the results that they are still not able to react in time. The 5Ma defense missile is similarly unable to a well coordinated dense saturation attack.

Therefore, looking at the development of offensive and defensive missile technologies, the anti-ship missile is unlimited, effective, and cheaper, while the shipborne defensive missiles are restricted, are unable to achieve high effectiveness and are very expensive, as well as being restricted by space aboard ship and costs. Therefore advances in anti-missile technology always lag behind advances in missile technology. For example, the French Universal Corporation and the German MBB Corporation have jointly developed the ANS anti-ship missile which flies at low altitude at speeds of Mach 2 and at intermediate altitudes at Mach 2.5 and has a maximum range of 180 kilometers. It can wave-hop the entire flight, and can fly at Mach 2.5 at intermediate altitudes for 160 kilometers, and approach the target at wave-hopping altitudes for the last 20 kilometers. It is also capable of snaking maneuvers to avoid being intercepted by close-range anti-missile systems. When it encounters heavy ECM jamming, it can use passive infrared guidance mode to search for and attack its target. Foreign publications call it a "hyper velocity, semi-intelligent terminal guidance anti-ship missile". It will replace the French "EXOCET" missiles and the German "Cormorant" missile. It will be placed into use in 1995. As Bixiai (phonetic), maker of the French Universal Corporations "EXOCET" missile stated, at the present time naval offensive power is greater than defensive power, and if defensive systems cannot deal with current missiles, then they will not be able to cope with the hyper velocity missiles currently under development.

In summary, future anti-ship missiles will be longer range, faster, have smaller radar cross sections, have more concealed paths and be more intelligent. Therefore, anti-ship missiles will be more of a threat. In order to turn this situation around, and improve the hit capability and combat power of ship, it will be necessary that they be equipped with a new generation anti-missile weapon, and the one with the best hope is the laser weapon.

V. Characteristics of laser weapons

1. Extremely high speed

Laser weapons fire laser beams which travel at the speed of light, $3X10^5$ km per second. Flight time to the target is almost zero, they hit as soon as they are fired, so there is no problem with lead or lead time.

2. They have a very high firing rate

10,000 laser pulses can be fired every second, and hooked up with a high speed computer, it is possible to fire 10,000 times per second at an incoming missile.

3. Strong mobility

Current ship-borne missiles and ship guns are powerless against a dense saturation attack. However, because laser weapon fire light beams which have a mass of almost zero, and do not generate recoil and are not affected by gravitational fields, they can quickly change the direction of fire by turning a mirror, switching from one target to another in a fraction of a second. They can fire at multiple incoming targets in different directions in a short time, so laser weapons are especially effective against dense saturation attacks by anti-ship missiles.

4. They have a high probability of intercept

Strong laser light can blind the sensors of optical guidance weapons from long range. At fairly close range they can cause the nose cone of the missile to break apart. At close range they can destroy the hard outer shell of the missile. Therefore, multiple firings at an incoming missile at different distances will use different damaging mechanisms against the target, and if the target is hit, it can be destroyed, with a dill rage of almost 100 percent[4].

5. Highly cost effective

U. S. Navy researchers believe that laser weapons cost less than tactical missiles. They have said: The cost of launching a tactical missile has increased from 50,000 Dollars to 2.5 million Dollars, and a single laser attack, according to estimates, after including hardware and personnel training costs, is only 10,000 Dollars.

6. Support services are simple

Laser weapon systems fire energy, and not traditional shells or missiles. Compared to the shells and missiles of ship gun and missile systems, the fuel they require is insignificant. Therefore, the support services for laser weapons are extremely simple.

Also, the U. S. Navy has another plan. This is to study nuclear reactor pile fired laser. Theoretically, this type of laser will have an unlimited supply of "ammunition".

VI. Status of development of ship-borne laser weapons

The United States Navy has paid a great deal of attention to laser weapons all along. Just as Allen Bage (phonetic), the planning manager at the United States Navy Research Laboratory for the "FIREPOND" laser radar for "Star Wars", stated, in order to deal with incoming weapons which are increasingly concealed and are increasingly faster, the United States Navy is currently doing research on using lasers for target detection, recognition and destruction. The totally electric drive ships being imagined will have about 50 to 100 million Watts of power, and the use of laser weapons would be no problem. Major achievements were reached as early as the seventies. As a close-range anti-missile weapon, its developmental stages and anti-missile testing have been as follow:

1974: The United States Navy began to carry out the plan of the Department of Defense, and launched research into ship-borne laser weapons such as the "Haishi" (phonetic, literally ocean rock) plan. This plan used a deuterium fluoride chemical laser as testing equipment, a large diameter mirror for focussing and the purpose was to study the overall technology of laser weapons and to conduct tests on the destructive power of high energy lasers in order to determine whether or not it would be worthwhile to use laser weapons on ships to intercept aircraft or missiles instead of conventional weapons.

1978: The United States Navy used a 400kW deuterium fluoride laser beam to destroy four TOW missiles in flight, making hits on all four, and hitting a UH-1 helicopter target aircraft.

1983: The United States used a 400kW pneumatic carbon dioxide laser to destroy five SIDEWINDER missiles in flight.

1985: On the night of September 6, the United States Navy used a 2MW deuterium fluoride laser at the White Sands Missile Range in missile destruction test. It destroyed the liquid rocket portion of a stationary ATLAS missile 1000 meters away. The continuous wave continuous operation time of the laser was three to five seconds, and the design standard was P/d=2.2mw/1.8M. When power density $I=10^6 W/cm^2$, range can be as great as 4.7 km, with an equivalent light spot diameter of $1.5cm^2$.

1987: On September 18, the United States Navy used a 2.2MW deuterium fluoride laser at the White Sands Missile Range to shoot down a BQM-34S target aircraft flying at 256 m/s at an altitude of 485 meters. On November 2 of the same year it shot down another target aircraft, this time the altitude was twice as high.

1989: In February, this system shot down a "VANDAL" missile[5] flying at Mach 2.2, thus fully demonstrating the effectiveness of this system. Recent research has indicated that the Navy's intermediate infrared advanced chemical laser and the "HAISHI" (phonetic) light beam direction finder MIRACL/SLBD can be matched together to form a high energy laser weapon system which takes up about the same space as the MK45 5in/54 ship gun and its ammunition hold. Using this high energy laser weapon system components to replace this ship gun system can result in a 15 percent reduction in weight, thus allowing a five percent increasing in ship stability (five percent reduction in pitch torque). This reduction in weight and reduction in pitch torque takes into consideration the increase in structural components. Because laser weapons systems are designed as a type of module, its dimensions and forms are consistent with those of current weapons, therefore, this helps in refitting current ships. The United States Navy is demonstrating the feasibility of a ship-borne laser weapons system advanced technology demonstration and testing plan which began in the 1995 fiscal year. The purpose of this plan is to solve problems with the shipborne adaptation of conceptually mature laser weapons. The United States Navy researchers are pressing for research of a type of experimental missile destroyer -the DDGLX which would be equipped with two high energy laser weapons systems.

1990: The French Navy used laser guns to destroy a missile infrared head and a metal plate representing an aircraft at 700 meters. This laser gun began system testing in 1984. Its fire control computer can execute five mission instructions per second. The model number is 68020. The improved version is 68030. As of the end of 1987 it had been tested more than 50,000 times.

The former Soviet Union has already installed two 3.7μm wavelength deuterium fluoride laser weapons systems which have an effective range of 10 kilometers on their KIROV cruisers.

In summary, because anti-ship missiles are already widely disseminated around the world, their threat is increasingly serious. Anti-missile defenses are becoming more and more difficult, and with current ship guns and missiles unable to ensure the ship's survivability, shipborne lasers have great developmental potential, and will undoubtedly occupy an important position on naval ships in the future.

BIBLIOGRAPHY

1. Liu Haijun, Modern Ships, 1991, (5), pp 21-26.

2. Yang Yugang, Modern Ships, 1992, (9), pp 32-36.

3. Zhu Jingming, Modern Ships, 1993, (11), pp 31-35.

4. Lin Liping, Xia Jinzhu, PLA Navy Guangzhou Academy of Naval Engineering Journal, 1993 (1), pp 77-79.

5. Bakker, G. de, Translated by Hu Shixing, Optics Countermeasures Communications, 1993, (11), pp 39-40.

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